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Descriptive epidemiology of morbidity and mortality in Minnesota dairy heifer calves

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Abstract

A prospective study was carried out on 845 heifer calves born during 1991 on 30 Holstein dairy farms in southeast Minnesota. The objectives of the study were to describe the epidemiology of morbidity and mortality in dairy calves from birth to 16 weeks of age (with an emphasis on respiratory disease), to examine individual calf and herd management practices as risk factors for calf morbidity and mortality, and to validate producer diagnosis of mortality. Incidence rates for all morbidity, enteritis, and pneumonia were 0.20, 0.15, and 0.10 cases per 100 calf-days at risk for the period of the study. Risk of enteritis was highest in the first 3 weeks of life, with pneumonia risk highest at 10 weeks of age. Case fatality rates averaged 11.8%, 17.9%, and 9.4% for all diagnoses, enteritis, and pneumonia, respectively. Average daily rates of gain from birth to 16 weeks of age differed between farms that had inadequate calf housing (0.8 kg day^{-1}) versus those with adequate calf housing (1.0 kg day^{-1}). Approximately half of the calves in the cohort (418) had blood samples taken monthly from birth until 16 weeks of age. Of the calves sampled, only 19 calves showed a four-fold rise in serum titers to respiratory viruses. Sixteen calves seroconverted to BVDV, two calves to IBRV, and one calf to PI3 virus. Of 98 calves less than 10 days of age tested for adequacy of passive transfer, 35 (35.7%) had serum immunoglobulin levels of less than 800 mg dl^{-1}. There were no significant differences in mortality or morbidity between calves that had adequate passive transfer and those that did not. The incidence of mortality was 0.08 deaths per 100 calf-days at risk; 64 calves died during the 16 months of the study. The risk of death was highest at 2 weeks of age. Enteritis was the most common cause of death (28 deaths, 44% of all deaths) followed by pneumonia (19 deaths, 30% of all deaths). Comparing producer diagnosis of mortality with necropsy results yielded sensitivities of 58.3% and 56% and specifici-

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ties of 93% and 100% for producer diagnoses of enteritis and pneumonia, respectively. The kappa statistic comparing producer diagnosis with necropsy result was 0.47. The most common pathogens isolated from calves that died of enteritis were rotavirus (five calves), and *Escherichia coli* (four calves). Pathogens isolated from pneumonic lungs included *Pasteurella multocida* (three calves), *Haemophilus somnus* (three calves), and *Pasteurella haemolytica* (one calf).

1. Introduction

Approximately 40–80% of all episodes of North American cattle diseases involve the respiratory system (Lillie, 1974). Bovine respiratory disease complex (BRDC) is a major health problem for cattle in the United States. BRDC involves three clinical syndromes: shipping fever of feedlot cattle, acute respiratory distress syndrome, and enzootic pneumonia of calves (Lillie, 1974). In Wisconsin, as much as 17% of the annual dairy calf crop may be lost due to respiratory disease (Smith et al., 1980). It has been estimated that 30% of Minnesota dairy calves are affected to some degree by respiratory disease (Baker, 1984).

Financial losses that result from calf pneumonia occur due to death loss, treatment cost, and decreased lifetime productivity. Michigan dairy producers estimated that respiratory disease in calves cost them $14.71 per calf-year (Kaneene and Hurd, 1990), while producers in California estimated that calfhood respiratory disease costs them $9 per calf-year (Sischo et al., 1990). Lifetime milk and calf production is decreased due to retarded growth rate (manifested as greater age at first calving) and increased probability of being culled from the milking herd. Calves that have experienced respiratory disease have been shown to be at an increased risk of culling when compared with herdmates of the same age (Curtis et al., 1989).

Enzootic pneumonia usually affects calves from 2 to 6 months of age, but the disease has been reported in calves from a few days old up to 1 year of age (Bryson et al., 1983). The pathogenesis of pneumonia involves the infection of calves shortly after birth by pathogens which are endemic residents in the calf population. The main route of infection is direct transmission via nasal secretions or droplets. This makes adequate ventilation of the calf's environment an important consideration (Roe, 1982). The pneumonic process may range from subclinical or chronic to fulminating acute (Kiorpes et al., 1988). Whether the disease is subclinical or fulminating depends on the virulence of the pathogens involved, the immune status of the calf, and environmental conditions (Jones and Webster, 1984).

Some recent epidemiologic studies have concentrated on identifying risk factors (and the inter-relationships between them) for morbidity and mortality both at the individual calf and herd levels. Finding consistency between herd level and individual animal risk factors strengthens hypotheses of causality. To date, only two prospective studies examining risk factors for morbidity and mortality in dairy calves from birth to weaning at the individual calf and herd levels have been published. The studies conducted in Ontario (Waltner-Toews et al., 1986a,Waltner-Toews et al., 1986b,Waltner-Toews et al., 1986c,Waltner-Toews et al., 1986d) and New York (Curtis et al., 1988a,Curtis et al., 1988b) relied on questionnaires and data collection by the farmers. In both studies, producer diagnosis and treatment were used to estimate morbidity. These studies were biased towards identifying risk factors contributing to scours rather than pneumonia. For example, calf housing groups were divided into the categories of individual pen, group pen, and hutch in one study and loose pen, tie stall, group pen, and hutch in the other. These divisions are unsuitable for determining housing as a risk factor for calf pneumonia, because they ignore ventilation and stocking density considerations. Neither study employed laboratory sampling (e.g. serology, microbiology, or postmortem) to help address issues of causality.

Both studies identified similar mortality rates (3.5% mortality in all calves). Mortality estimates were derived by dividing the number of dead calves by the number of liveborn calves in a 3 month period in one study (Waltner-Toews et al., 1986a) and by dividing the number of calves dead between 1 and 90 days of age by the number of calves alive at 1 day of age in the other (Curtis et al., 1988a). Herd level factors affecting mortality rates were herd size, type of calf housing, and a policy of attending calvings and ensuring that calves received colostrum promptly at birth. Individual risk factors for mortality included dystocia, sire, place of calving, and whether navel treatment was used.

The objectives of this study were to (1) describe the epidemiology of ECP in Holstein dairy calves from birth to 16 weeks of age, (2) examine individual calf and herd management practices as risk factors for calf morbidity and mortality, and (3) to validate producer-diagnosed causes of neonatal calf mortality. The study was conducted in 30 representative Dairy Herd Improvement Association (DHIA) member dairy herds in southeast Minnesota.

2. Materials and methods

Thirty Holstein dairy herds with membership in the DHIA were involved in this prospective cohort study, conducted between January 1991 and May 1992. These randomly selected herds are located in Dakota and Rice counties in Minnesota and are representative of DHIA herds in the state of Minnesota as a whole, based, on milk production, farm size, and cattle numbers. Minnesota DHIA herds in 1991 had an average cow number of 52 and an average annual rolling herd milk production of 7717 kg per cow. Rice county DHIA herds had an average size of 52 cows, and a rolling herd average of 7507 kg, while Dakota county DHIA herds had an average of 61 cows and a rolling herd average of 7698 kg. Use of a random sample ensured that producers with a variety of management abilities were included. The randomization mechanism involved numbering the herds on the list of DHIA members in Rice and Dakota counties that had more that 40 cows. A random number list was generated using a computer program and herds were contacted in order, using the random number list. Additional producer selection criteria included regular use of veterinary services, herd size of greater than 40 cows, milk sales revenue comprising a major component of total farm income, and the producers must raise their own replacement heifer calves.

At the beginning of the study, a pretested questionnaire which has been developed and modified based on those of Curtis (Curtis et al., 1988a,Curtis et al., 1988b) and one designed by the National Animal Health Monitoring System for the 1992 National Dairy Heifer Evaluation Project was administered by personal interview by one of the investigators to the producers in the study to determine their calf management practices, including feeding, housing, and vaccination (a copy of the questionnaire is available on request). Predetermined standards were used to assess the adequacy of calf housing, based on the type of housing, location, division of age groups, ventilation adequacy, manure handling effectiveness, and stocking density. Two different prepared check-off forms were distributed to producers for recording individual calf data from birth to 16 weeks of age for all heifer calves born on the farm for the duration of the study (copies of these forms are available on request). The 'birth sheet' was completed by producers at the time of birth of a heifer calf. It contained information about the sire and dam, as well as events surrounding the calf's birth (e.g. time of delivery, ease of delivery, treatments given at birth). The 'treatment sheet' was used to record all diagnoses and treatments given by producers. Any occurrence of illness was recorded for each calf. All calves in the study were individually identified using ear tags. Individual calf sheets were collected monthly and data stored on a computer herd management program (DairyCHAMP®; DairyCHAMP®, University of Minnesota College of Veterinary Medicine, 385 AnSci/Vet Med, 1988 Fitch Avenue, St. Paul, MN 55108, USA). Monthly herd visits were conducted to collect calf sheets and serologic samples for respiratory pathogens, using the standard serologic tests of the Minnesota Veterinary Diagnostic Laboratory for infectious bovine rhinotracheitis, bovine virus diarrhea virus, parainfluenza virus 3, and bovine respiratory syncytial virus. Every other heifer calf that was born on each farm during the study was sampled monthly from birth until 16 weeks of age. These calves also received a brief physical examination and were weight taped at each monthly visit. In addition, physical examinations were performed on any calf that the producer identified as 'sick', in order to facilitate assessment of morbidity. Also, any calves that were less than 1 week of age at the time of the visit were sampled for serum immunoglobulin levels in order to assess the effectiveness of colostrum feeding on each farm, using the sodium sulfite turbidity test (Bova-S™, Veterinary Medical Research and Development, Inc., PO Box 502, Pullman, WA 99163, USA).

Carcasses of as many of the heifers that died between birth and 16 weeks of age during the study as possible were retrieved within 24 h and necropsied according to standard protocol at the Minnesota Diagnostic Laboratory, in order to validate producer diagnosis of mortality. Producer diagnoses were obtained at the time of calf retrieval from the farm. Postmortems were performed in similar studies of pneumonia in feedlot cattle and preweaning pig mortality and were useful in the validation of mortality (Martin et al., 1980; Vaillancourt et al., 1990).

Data analysis involved calculating incidence rates for morbidity and mortality by dividing the number of events by the number of calf-days at risk during the time period of interest. Multiple events for a single calf were noted; events were considered independent if a minimum of 3 days elapsed between them. Effects of seasonality were assessed by dividing calves into winter (1 November–30 April) and summer groups, based on date of birth. All statistical tests were two-tailed and used an alpha of 0.05. A chi-square test examined the differences between morbidity and mortality between the two seasonal groups. A weighted least squares regression was used to examine the relationship between farm level rate of gain and morbidity and mortality. Chi-square tests were used to compare the farm level rates of gain between those farms with adequate calf housing and those that had inadequate housing. Age of occurrence for morbidity and mortality were also calculated. A simple linear regression model was used to examine the relationship between immunoglobulin status and rate of gain. The relationship between producer diagnosis of mortality and necropsy diagnosis was explained in terms of sensitivity and specificity, using necropsy as the gold standard. All statistical analyses were performed using the Statistix program (Statistix, Analytical Software, PO Box 130204, St. Paul, MN 55113, USA) on a microcomputer.

3. Results

In November of 1990 the previously described questionnaire was personally administered to the 30 producers to determine their management practices, which we believe define the herd level risk factors for the study (Tables 1–4). One farm was lost during the study. We believe that quality of data was excellent on all farms. Bull calves were

Table 1
Characteristics of the 30 Minnesota (USA) participating dairy farms

Number of lactating cows	Mean	61.1
	Range	40–112
Average annual rolling herd milk production per cow for 1991 (kg)	Mean	8085
	Range	(6034–10055)
Number of calves born dead in the last 90 days	Mean	1.5
	Range	0–5
Number of calves born alive in the last 90 days	Mean	20.1
	Range	8–36
Number of heifer calves that died in the last 90 days	Mean	1.1
	Range	0–5
Leading cause of illness in calves in the last 90 days	None	4
	Scours	18
	Pneumonia	7
	Unknown	1
Most common reason to cull adult cows	Low production	14
	Reproduction	13
	Injury	3
Organization of farm	Family farm	26
	Partnership	3
	Corporation	1
Primary calf caretaker	Farmer/family	29
	Hired help	1
Education of calf caretaker	Grade school	1
	High school	17
	College/Tech	12

Table 2
Management of calving on 30 Minnesota (USA) dairy farms

Dry cow vaccination	*E. coli*	4
	Leptospirosis	15
	Rota/coronavirus	1
	IBR	16
	BVD	16
	PI3	16
	BRSV	16
Predominant calving facilities	Maternity pen — separate facility	4
	Maternity pen — main barn	12
	Drylot/pasture	4
	Stanchion	8
	Loose housing	2
Mean length of time that cows are in maternity pen prior to calving (days)	0–2	8
	3–5	3
	6–10	5
	> 10	14
Bedding in maternity area	Straw	22
	Corncobs/stalks	6
	None	2
Frequency of cleaning of maternity area	After every calf	8
	Every 2–4 calves	8
	After > 4 calves	14
Routine assistance of calvings	Routinely	10
	Rarely/never	20
Treatments to calves at birth	Scours vaccine	10
	Dip navel	14
	Vitamins	2
	Inject antibiotics	4
Colostrum feeding	Hand feed only	14
	Suckling/hand feed	16
Method of colostrum feeding	Bottle	27
	Esophageal feeder	3
Amount of colostrum at first feeding	1.9 l	27
	> 1.9 l	3
Type of colostrum fed	Fresh from dam	29
	Pooled (frozen)	1

sold before 2 weeks of age on all farms. The primary calf caretaker was the farmer or a member of the farmer's family on 29 of the farms. Vaccinating pregnant cows against *Escherichia coli* and rotavirus/coronavirus was used by only 17% of the farms in the study. Maternity pens were used on 16 farms (53% of all farms), although only four of those farms located the maternity pens separate from the milking herd. Straw was the most common bedding used in the maternity area (73%), and the area was cleaned after every calf on only 27% of the farms. Colostrum was hand-fed on all farms, while 16 of the farms would allow calves to suckle colostrum from the cow. These findings are similar to previous published research (Waltner-Toews et al., 1986a).

Table 3
Management of preweaned calves on 30 Minnesota (USA) dairy farms

Time calf removed from dam	At birth	10
	After first nursing	15
	Before 24 h of age	4
	After 24 h of age	1
Type of bedding used for calves	None	3
	Straw	21
	Corncobs/stalks	6
Frequency of cleaning calf housing	After every calf	18
	After every 2 calves	8
	After > 2 calves	4
Frequency of movement of hutches	After every calf	3
	After every 2 calves	2
	After > 2 calves	4
	Never	5
Type of milk fed	Fresh milk	3
	Discarded milk	1
	Milk replacer	26
Type of concentrates offered	Commercial calf feed	23
	Home-made calf feed	7
Timing of first hay feeding	Less than 2 weeks of age	7
	2–6 weeks of age	5
	Older than 6 weeks of age	18
Availability of fresh water	Always	10
	Never	17
	Summer only	3

The adequacy of calf housing was also visually assessed using the previously described standards (Table 5). A farm was considered 'adequate' if it passed all listed criteria. For preweaning housing, seven farms had adequate housing in the winter, eight

Table 4
Management of calf weaning on 30 Minnesota (USA) dairy farms

Basis of weaning	Age	13
	Weight	5
	Grain intake	12
Age at weaning	4–6 weeks of age	5
	6–8 weeks of age	18
	8–12 weeks of age	4
	12–16 weeks of age	3
Weight at weaning (kg)	Less than 64	2
	65–73	15
	74–82	11
	83–91	2
Criteria for grouping weaned calves	Age	8
	Size	22
Number of weaned calves per group	Mean	6.97
	Range	2–17

Table 5
Standards for adequacy of ventilation of calf housing [a]

1	One calf per hutch
2	Minimum of 1.2 m between hutches
3	Hutches further than 15.2 m from exhaust outlets from other buildings
4	Air flow in group housing from younger animals toward older animals
5	5.7 m^3 of air space per calf in buildings of any type
6	Barrier walls to separate age groups of animals housed in buildings of any type
7	Enough fan capacity in mechanically ventilated buildings to perform the required four changes per hour in winter as well as the 40 per hour needed in the summer
8	Intake velocity of mechanically ventilated buildings to be between 61 and 244 m min^{-1}
9	Temperature range from 0 to 10°C in warm housing in the winter
10	Humidity levels between 50 and 80% in buildings of any type
11	As a measure manure-handling effectiveness, ammonia concentrations shall be less than 10 ppm
12	Naturally ventilated buildings to be located more than 15.2 m from other building exhaust ports or other naturally ventilated buildings
13	Inside air temperature 10°C warmer in unheated buildings than outside temperature in the winter

[a] Bates and Anderson, 1984; L.D. Jacobsen, personal communication, 1990.

farms were adequate in the summer. Hutches were used in this study by 30% of the farms in the winter and 43% of the farms in the summer; previous studies reported that 32% (Curtis et al., 1988a) and 17% (Waltner-Toews et al., 1986a) of farms used hutches for preweaned calves. Individual stalls were used by 60% of the producers in this study in the winter and 43% in the summer, compared with 12% (Curtis et al., 1988a) and 50% (Waltner-Toews et al., 1986a) of producers in other studies. Postweaning housing was adequate on six farms in the winter and the summer (Table 6).

Eight hundred and forty-five heifer calves were born into the cohort. Calf-days at risk contributed to the study averaged 2850 days per farm (range 951–5284, SD 1208). Producers treated 203 calves (24.0% of all calves) for illness during the study, yielding an overall morbidity rate of 0.2 calves treated per 100 calf-days at risk (0–0.8, SD 0.2) (Fig. 1). Calves were treated most often for enteritis (128 cases) and pneumonia (64) (Table 7); other reasons for treatment included depression/off feed (5), navel ill (4), musculoskeletal disease (1), and ringworm (1). Treatment rates on all farms for enteritis averaged 0.15 cases per 100 calf-days at risk (0–0.7, SD 0.2) (Fig. 2), while rates for pneumonia for all farms averaged 0.1 cases per 100 calf-days at risk (0–0.7, SD 0.2) (Fig. 3). Risk of enteritis was highest at birth (0.9 cases per 100 calf-days at risk) and declined rapidly to 3 weeks of age (0.1 cases per 100 calf-days at risk) (Fig. 4). Risk of pneumonia was highest at birth (0.18 cases per 100 calf-days at risk) and again at 10 weeks of age (0.12 cases per 100 calf-days at risk) (Fig. 5). Case fatality rates on all farms averaged 11.8% for all diagnoses, 17.9% for enteritis, and 9.4% for pneumonia (Table 7). No significant effects of season were seen for morbidity or mortality, using the chi-square test ($\chi^2 = 8.06$, df = 29, $P = 0.006$).

Table 6
Adequacy of calf housing on 30 Minnesota (USA) dairy farms

Type of housing	Preweaning adequacy	Winter	Summer
Individual housing in the same airspace as adult cattle	Adequate	0	0
	Inadequate	2	3
Group housing in the same airspace as adult cattle	Adequate	0	0
	Inadequate	1	1
Individual housing in different airspace than adult cattle	Adequate	3	2
	Inadequate	13	7
Group housing in different airspace than adult cattle	Adequate	0	0
	Inadequate	2	3
Hutches	Adequate	4	6
	Inadequate	5	7
Type of housing	Postweaning adequacy	Winter	Summer
Group housing in the same airspace as adult cattle	Adequate	0	0
	Inadequate	4	5
Group housing in different airspace than adult cattle	Adequate	6	6
	Inadequate	20	18

Treatment of disease in the calves was consistent between farms. All calves with pneumonia were treated with injectable antibiotics. Calves with enteritis were treated with injectable antibiotics only (60 calves), oral electrolyte fluids (50 calves), and a combination of oral fluids and injectable antibiotics (12 calves).

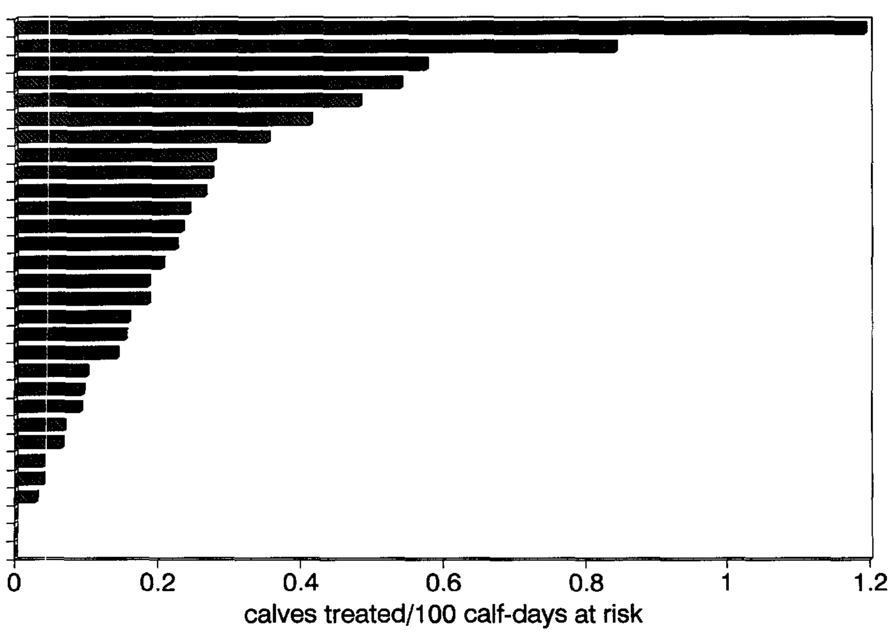

Fig. 1. Overall morbidity rates in 1991 for 845 Holstein heifer calves on 30 Minnesota (USA) dairy farms.

Table 7
Morbidity measurements in 1991 involving 845 Holstein heifer calves on 30 Minnesota (USA) dairy farms

Diagnosis	# [a] (%)	CFR [b]	Days of treatment			Age at diagnosis (days)		
			MED	MIN	MAX	MED	MIN	MAX
Enteritis	128 (15.2)	17.9	8	1	51	2	0	14
Pneumonia	64 (7.6)	9.4	44	1	109	1	0	6
All	203 (24.0)	11.8	11	1	109	2	0	14

[a] Number of cases.
[b] Case fatality rate.

Average daily rates of gain differed between farms in the study. Average rates of gain for calves from birth to 16 weeks of age were calculated at the farm level. Rates of gain averaged 0.8 kg day^{-1} for all farms (0.5–1.1, SD 0.2) (Fig. 6). For 22 farms with inadequate housing, daily rates of gain averaged 0.8 kg day^{-1} (0.5–1.0, SD 0.1), while farms with adequate calf housing (eight farms) averaged 1.0 kg day^{-1} (0.9–1.1, SD 0.1). Although the difference in rates of gain between farms that had adequate calf housing when compared with those with inadequate housing was significant ($\chi^2 = 7.57$, df = 29, $P = 0.004$), the association is confounded by rolling herd milk production average between the two groups, after stratification based on median rolling herd milk

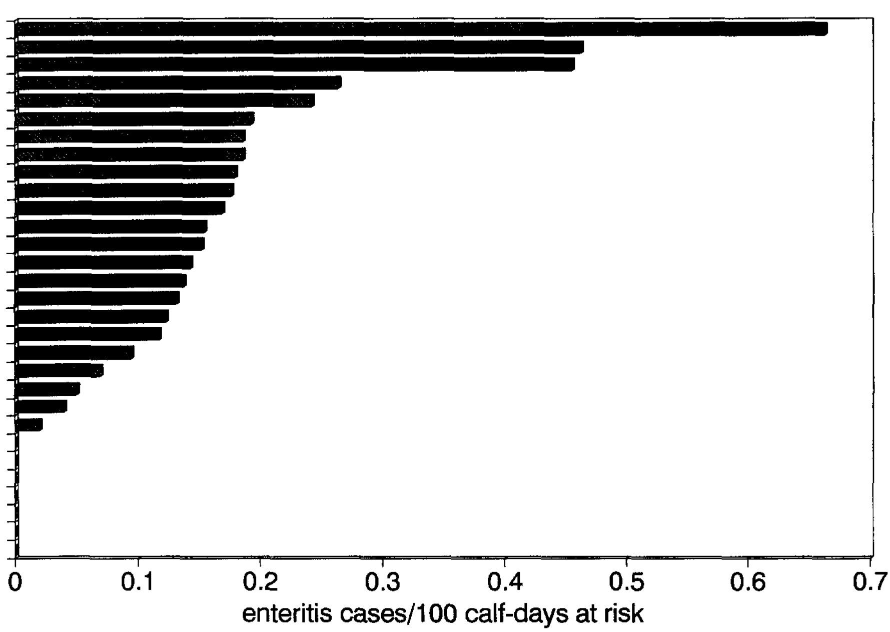

Fig. 2. Enteritis rates in 845 Holstein heifer calves on 30 Minnesota (USA) dairy farms for 1991.

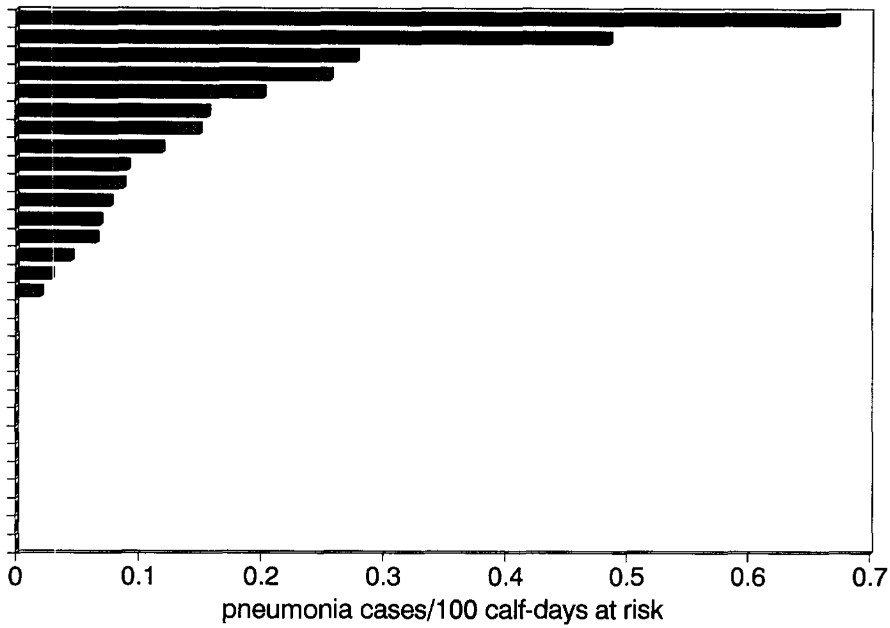

Fig. 3. Pneumonia rates in 845 Holstein heifer calves on 30 Minnesota (USA) dairy farms for 1991.

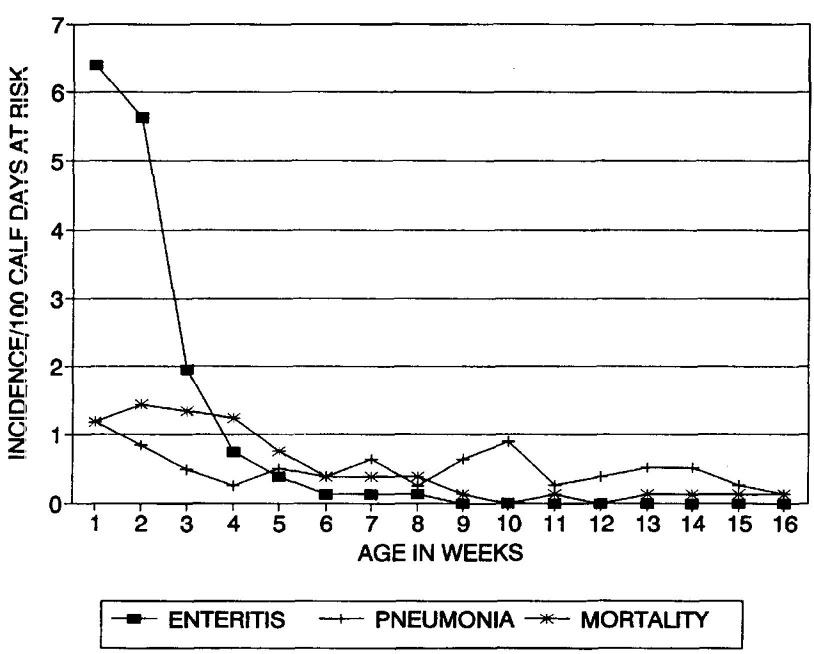

Fig. 4. Average daily rate of gain in 845 Holstein heifer calves on 30 Minnesota (USA) dairy farms in 1991.

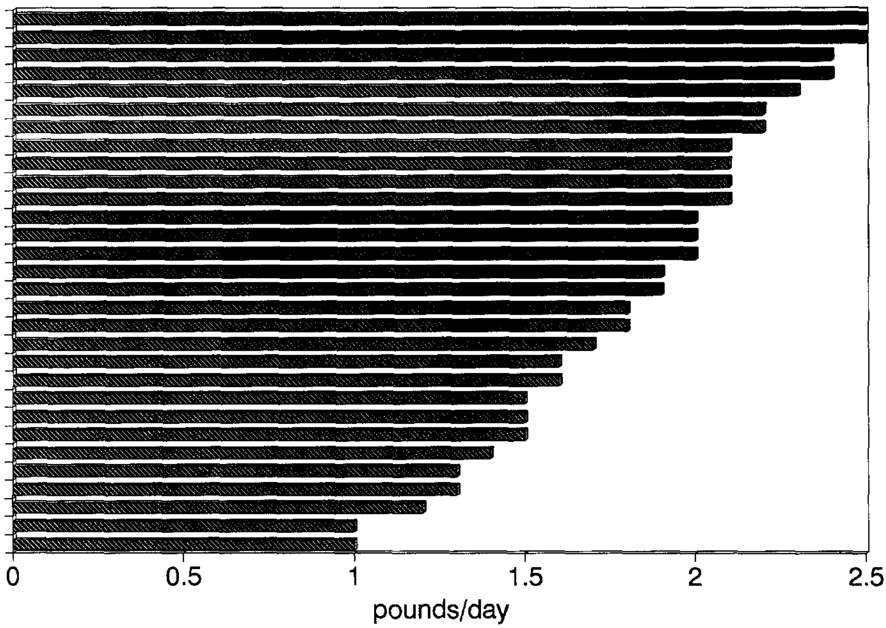

Fig. 5. Incidence rates by age for enteritis, pneumonia, and mortality by age in 845 Holstein heifer calves on 30 Minnesota (USA) dairy farms for 1991.

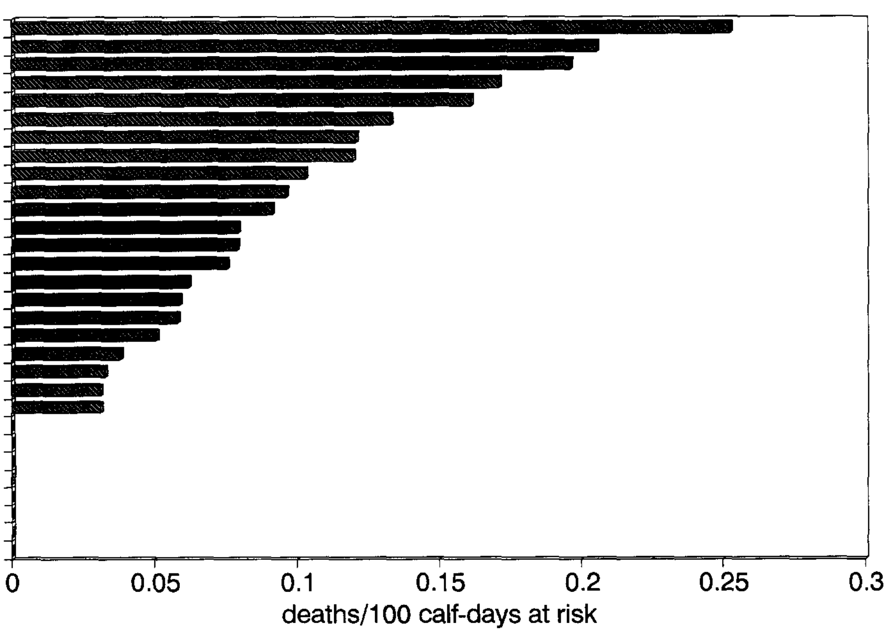

Fig. 6. Mortality rates for 845 Holstein heifer calves in 1991 on 30 Minnesota (USA) dairy farms.

production average and finding a significant Mantel–Haenzel chi-square value ($\chi^2 = 3.02$, df = 14, $P = 0.05$). Farms with adequate calf housing had a mean rolling herd average for 1992 of 9090 kg (range 7504–10000), while farms with inadequate calf housing had a mean rolling herd average of 7722 kg (6036–10054). In addition, there were no significant differences between average daily rate of gain between calves that were treated by producers (mean 0.8 kg day^{-1}, SD 0.1) and calves that were not treated (0.8, SD 0.1) during the study, based on an unweighted least squares linear regression ($P = 0.87$). No significant results were found using serum immunoglobulin level in an unweighted least squares regression for morbidity or mortality ($P = 0.63$).

Four hundred and eighteen heifer calves were sampled from the month of birth to 16 weeks of age for evidence of seroconversion to the respiratory viruses. Of these calves, only 19 showed a four-fold increase in serum titer: 16 calves to BVDV, two to IBR, and one calf to PI3. The 19 calves were from 12 different herds. The mean age at time of seroconversion was 60 days (this does not include the six heifers that were involved in an outbreak of pneumonia on one farm and seroconverted to BRSV). Effectiveness of colostral transfer was assessed in 98 calves by using the sodium sulfite turbidity test. The 98 calves were a convenience sample from all 30 herds, with some herds represented more than others. Of these 98 heifers, 35 had failure of passive transfer (serum IgG level of less than 800 mg dl^{-1}). Comparing the 35 calves with failure of passive transfer (FPT) with the 63 calves that had adequate passive transfer, there were no significant differences between the two groups with respect to the number of calves that became ill (seven in the FPT group versus 13 in the normal group) or calves that died (five in each group), based on a chi-square test ($\chi^2 = 0.13$, df = 97, $P = 0.71$). Average daily rate of gain was not significantly different between the two groups ($\chi^2 = 34$, df = 97, $P = 0.63$). Serum immunoglobulin level was not significantly correlated with daily rate of gain ($r = 0.04$, df = 97, $P = 0.69$), and a simple linear regression model showed no significant relationship between immunoglobulin status and rate of gain ($r^2 = 0.008$, $P = 0.73$).

Sixty-four heifers (7.6% of all calves) died during the study, yielding an overall mortality rate of 0.08 deaths per 100 calf-days at risk (0–0.3 ± 0.08) (Fig. 6). The median age of death was 15.2 days (1–112 ± 24.7 days). The mortality rate was highest at 2 weeks of age (0.2 deaths per 100 calf-days at risk) and then declined to 16 weeks of

Table 8
Mortality results for 44 Holstein heifer calves in 1991 from 30 Minnesota (USA) dairy farms

Producer diagnoses	Necropsy results			
	Scours	Pneumonia	Trauma	Joint ill
Scours	14	1	0	0
Pneumonia	0	9	0	0
Trauma	0	0	3	0
Joint ill	0	0	0	1
Unknown	10	6	0	0
Total	24	16	3	1

Eight calves were diagnosed with 'other' diseases by producers: three atresia colis, two abomasal ruptures, one small intestinal volvulus, and one septicemia were found on postmortem of these calves.

age (Fig. 4). The most common cause of death was enteritis (28 deaths, 43.8% of all deaths), followed by pneumonia (19 deaths, 29.7% of all deaths). Of the 64 calves that died during the study, postmortems were performed on 52 calves. Comparing producer diagnosis with postmortem result, producer diagnosis of mortality due to enteritis had a sensitivity of 58.3% (95% CI 61.3%, 55.3%), and a specificity of 93% (95% CI 93.5%, 92.5%). Producer diagnosis of mortality due to pneumonia had a sensitivity of 56% (95% CI 59%, 53%) and a specificity of 100% (Table 8). Specific pathogens were identified at postmortem in some of the cases. The most common pathogens isolated from heifers that died of enteritis were rotavirus (five), *E. coli* (four), and BVDV (one). Pathogens isolated from pneumonic lungs included *Pasteurella multocida* (three), *H. somnus* (three), and *Pasteurella haemolytica* (1). No respiratory viruses were isolated from pneumonic calves.

4. Discussion

The average herd size of 61 lactating cows in this study is similar to other studies of this type (Waltner-Toews et al., 1986a,Waltner-Toews et al., 1986b,Waltner-Toews et al., 1986c,Waltner-Toews et al., 1986d; Curtis et al., 1988a,Curtis et al., 1988b). Because the focus of this study was on enzootic calf pneumonia, assessment of calf housing with emphasis on ventilation was critical in determining adequacy of calf housing. Many housing schemes are adequate from the standpoint of enteritis prevention, but fail with regards to prevention of respiratory disease. The most common reasons that preweaning calf housing was considered inadequate in this study were that calves were housed in close proximity to adult animals, intake and exhaust areas in mechanically ventilated housing were often sealed in the winter, and hutch location was improper. Weaned calf housing was most often inadequate because of inappropriate stocking density and proximity to older cattle.

The morbidity rates (both crude and disease-specific rates) in this study were similar to rates found in other studies of this type (Waltner-Toews et al., 1986a,Waltner-Toews et al., 1986b,Waltner-Toews et al., 1986c,Waltner-Toews et al., 1986d; Curtis et al., 1988a,Curtis et al., 1988b). The treatments used by producers in this study were similar to those reported in other studies (Waltner-Toews et al., 1986a; Curtis et al., 1988a).

The differences in farm level rates of gain from birth to weaning were interesting. Nutrition was fairly constant between farms, and there was no correlation between lower rates of gain and higher morbidity rates. One possible reason for the decreased rates of gain on farms with inadequate housing was subclinical enzootic pneumonia. Subclinical pneumonia is not recognized by most producers because clinical signs are transient or unapparent. Fever and increased resting respiratory rate are the most sensitive indicators of subclinical pneumonia. Producers rarely take a calf's rectal temperature unless it is anorectic or depressed. In this study however, the association between housing and poor weight gains is confounded by rolling herd milk production average, which may be a surrogate for managerial ability. Perhaps a larger cohort or more intense observation of calves in various housing schemes (e.g. daily rectal temperatures) would increase detection of enzootic pneumonia.

The lack of seroconversion to the respiratory viruses for calves that were diagnosed with pneumonia as well as those identified as clinically normal may indicate that for the enzootic form of dairy heifer calf pneumonia, viruses do not play a role in the initiation of the syndrome. Detection of seroconversion may have been blocked by passive immunity, but this immunity should have been absent by 2–3 months of age; calves in this study were sampled until 4 months of age. Also, approximately one third of the calves in this study had failure of passive transfer, and therefore should have seroconverted if exposed to a viral challenge during the sampling period. If this is true, then other initiators (e.g. stress, poor air quality) are decreasing the effectiveness of the calf's respiratory defense mechanisms and predisposing calves to invasion by bacterial agents. This indicates that quality of housing and specifically ventilation are important with regards to prevention of respiratory disease in the dairy calf.

The proportion of calves (35.7%) with failure of passive transfer in this study is greater than in previous research (Besser et al., 1991). Traditionally, failure of passive transfer has been associated with increased morbidity and mortality in calves (Gay et al., 1965; Boyd, 1972). However, a recent study did not demonstrate this difference (Caldow et al., 1988). In the recent National Dairy Heifer Evaluation Project, 41% of the 2177 calves tested had serum immunoglobulin levels of less than 1000 mg dl^{-1}. Failure of passive transfer in our study was not a risk factor for mortality, but a larger or more representative sample of calves should be sampled before definitive conclusions can be drawn. In our study, a convenience sample was used for the passive transfer portion of the study. To detect a difference in mortality between calves with FPT and those with adequate passive transfer with alpha = 0.05 and beta = 0.80, 408 calves would be needed.

Mortality rates in this study are also similar to those in previous studies (Waltner-Toews et al., 1986a; Curtis et al., 1988a). The highest risk of death was in 2-week-old calves, which is similar to previous research. Unexpectedly, death from enteritis was most common in young calves, with deaths in older calves (6–12 weeks of age) most often due to pneumonia. The pathogens isolated from dead calves were unsurprising with two exceptions. *Cryptosporidia* spp. (thought by some to be an important intestinal pathogen in the calf) was not identified in any of the dead calves. In addition, respiratory viruses were not isolated from any of the dead calves, whether they were pneumonic or not.

Validation of producer diagnosis of calf mortality has not been performed in the dairy industry, unlike the beef and swine industries (Martin et al., 1980; Vaillancourt et al., 1990). The sensitivity and specificity of producer diagnosis for enteritis and pneumonia were not unlike the accuracy found for producers in other industries. A kappa statistic (which indicates the maximum possible agreement beyond chance) of 0.47 indicates only moderate agreement. Removing the 'unknown' producer diagnoses would increase sensitivity, specificity, and the kappa statistic considerably. Reporting an 'unknown' diagnosis could indicate lack of diagnostic ability, or simply indecision regarding proper diagnosis. If the accuracy of producer diagnosis of neonatal calf mortality is an indicator of overall producer diagnostic skill, the validity of all producer supplied health information may be in question. Information regarding events that need no interpretation, such as number of calves born or time of weaning are likely to be more reliable than those that require interpretation by the producer, such as diagnosis of calf morbidity and mortality.

5. Conclusions

The descriptive epidemiology in this study is similar to the other two prospective studies on dairy calf morbidity and mortality. The incidence rates for overall morbidity, enteritis, and morbidity due to pneumonia were 0.2, 0.15, and 0.10 cases per 100 calf-days at risk, respectively. The risk of morbidity and mortality was highest in the first 3 weeks of life. Seven farms reported no cases of enteritis, while 14 farms had no cases of pneumonia during the study. The average daily rate of gain for the birth to 16 week of age period varied between farms, with rates ranging from 0.5 to 1.1 kg per day. Farms with adequate calf housing tended to have higher rates of gain, but this association was confounded by rolling herd milk production average, which may be a surrogate for managerial ability. The overall mortality rate for the study was 0.08 deaths per 100 calf-days at risk. A total of 19 calves demonstrated a four-fold increase in serum titer to the respiratory viruses from birth to 16 weeks of age. Failure of passive transfer was identified in 35 of 98 (35.7%) calves tested. There were no significant differences between adequacy of passive transfer and health status. Eight farms reported no deaths during the study. A total of 64 heifer calves died during the study. Enteritis was the most common cause of death (44% of all deaths), followed by pneumonia (30% of all deaths). Comparing producer diagnosis of mortality with postmortem result on 52 calves, producer diagnosis of death due to enteritis had a sensitivity of 58.3% and a specificity of 93%. Producer diagnosis of death due to pneumonia had a sensitivity of 56% and a specificity of 100%. The kappa statistic comparing producer diagnosis of mortality with necropsy diagnosis was 0.47, indicating moderate agreement.

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References

Baker, J.C., 1984. Studies on the bovine respiratory syncytial virus. University of Minnesota, PhD Thesis.

Bates, D.W. and Anderson, J.F., 1984. Environmental design for a total animal health care system. Bov. Pract., 19: 4–20.

Besser, T.E., Gay, C.C. and Pritchett, L., 1991. Comparison of three methods of feeding colostrum to dairy calves. J. Am. Vet. Med. Assoc., 198: 419–422.

Boyd, J.W., 1972. The relationship between serum immunoglobulin deficiency and disease in calves: a farm survey. Vet. Rec., 90: 645–649.

Bryson, D.G., McNulty, M.S., Logan, E.F. and Cush, P.F., 1983. Respiratory syncytial virus pneumonia in young calves: clinical and pathological findings. Am. J. Vet. Res., 44(9): 1648–1655.

Caldow, G.L., White, D.G., Kelsey, M., Peters, A.R. and Solly, K.J., 1988. Relationship of calf antibody status to disease and performance. Vet. Rec., 122: 63–65.

Curtis, C.E., Erb, H.N. and White, M.E., 1988a. Descriptive epidemiology of calfhood morbidity and mortality in New York Holstein herds. Prev. Vet. Med., 5: 293–307.

Curtis, C.E., Erb, H.N. and White, M.E., 1988b. Path model of individual calf risk factors for calfhood morbidity and mortality in New York Holstein herds. Prev. Vet. Med., 6: 43–62.

Curtis, C.R., White, M.E. and Erb, H.N., 1989. Effects of calfhood morbidity on long-term survival in New York Holstein herds. Prev. Vet. Med., 7: 173–186.

Gay, C.C., Anderson, N., Fisher, E.W. and McEwan, A.D., 1965. Gammaglobulin levels and neonatal mortality in veal market calves. Vet. Rec., 77: 5.

Jones, C.D.R. and Webster, J.F., 1984. Relationship between counts of nasopharyngeal bacteria, temperature, humidity, and lung lesions in veal calves. Res. Vet. Sci., 37: 132–137.

Kaneene, J.B. and Hurd, H.S., 1990. The National Animal Health Monitoring System in Michigan. III. Cost estimates of selected dairy cattle diseases. Prev. Vet. Med., 8: 127–140.

Kiorpes, A.L., Butler, D.G., Dubielzig, R.R. and Beck, K.A., 1988. Enzootic pneumonia in calves: clinical and morphologic features. Comp. Cont. Ed., 10(2): 248–258.

Lillie, L.E., 1974. The bovine respiratory disease complex. Can. Vet. J., 15: 233–22.

Martin, S.W., Meek, A.H., Davis, D.G., Thomson, R.G., Johnson, J.A., Lopez, A., Stephens, L., Curtis, R.A., Prescott, J.F., Rosendal, S., Savan, M., Zubaidy, A.J. and Bolton, M.R., 1980. Factors associated with mortality in feedlot cattle: the Bruce County Beef Cattle Project. Can. J. Comp. Med., 44: 1–10.

Roe, C.P., 1982. A review of the environmental factors influencing calf respiratory disease. Agric. Meteorol., 26: 127–144.

Sischo, W.M., Hird, D.W., Gardner, I.A., Utterback, W.W., Christiansen, K.H., Carpenter, T.E., Danaye-Elmi. C. and Heron, B.R., 1990. Economics of disease occurrence and prevention on California dairy farms: a report and evaluation of data collected for the National Animal Health Monitoring System, 1986–1987. Prev. Vet. Med., 8: 141–156.

Smith, P.C., Reed, D. and Lauerman, L., 1980. Revised proposal on bovine respiratory disease. NC-107, pp. 1–24.

Vaillancourt, J.-P., Stein, T.E., Marsh, W.E., Leman, A.D. and Dial, G.D., 1990. Validation of producer-recorded causes of preweaning mortality in swine. Prev. Vet. Med., 10: 119–130.

Waltner-Toews, D., Martin, S.W., Meek, A.H. and McMillan, I., 1986a. Dairy calf management, morbidity, and mortality in Ontario holstein herds. I. The data. Prev. Vet. Med., 4: 103–124.

Waltner-Toews, D., Martin, S.W. and Meek, A.H., 1986b. Dairy calf management, morbidity, and mortality in Ontario holstein herds. II. Age and seasonal patterns. Prev. Vet. Med., 4: 125–135.

Waltner-Toews, D., Martin, S.W. and Meek, A.H., 1986c. Dairy calf management, morbidity, and mortality in Ontario holstein herds. III. Association of management with morbidity. Prev. Vet. Med., 4: 137–158.

Waltner-Toews, D., Martin, S.W. and Meek, A.H., 1986d. Dairy calf management, morbidity, and mortality in Ontario holstein herds. IV. Association of management with mortality. Prev. Vet. Med., 4: 159–171.